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# Preparation and the Use of Demineralized Water for Reciprocating Engine-Driven Power Plants in Azerbaijan

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Production of electric and thermal power on the basis of reciprocating engines finds an increasingly wide application in many countries of the world. These power plants equipped with internal combustion engines can be constructed rapidly (usually within several months). For example, a 10-MW module based on three engines can be made by Finnish manufacturer Wartsila in about 80 days, and its installation takes 12 days. The pay-back time for a power unit with the output of 1 MW and 8000 operating hours per year is 2.3 years. The efficiency of reciprocating gas engines with the power capacity from 2 MW to 6 MW is 39–42% [1].

In cooling systems of reciprocating engines there are also used, besides air (fan) cooling, water (closed-cycle) cooling by a mixture of desalted water, antifreeze, and a corrosion inhibitor. It is most economically advantageous and environmentally safe to produce and use demineralized water for power plants by the membrane technology. In this case the quality of desalted water meets the requirements contained in the Russian standards "Service Instruction Related to Power Plants," [2, 3] which Azerbaijan adheres to as well.

The cost of production of desalted water at membrane units is lower than when using chemical desalination [3, 4]. Capital costs of preliminary water purification prior to membrane desalination are about 60–70% of the cost of a desalination plant, or 25–29% of the cost of process equipment needed for a water treatment plant [5]. The volume of waste water at membrane desalination is equal to 25–40% of the plant capacity. In its composition the source water is concentrated by a factor of 2 or 3, and is not corrosive. The "brine" (or effluent) is inadmissible to be discharged in sewerage [5, 6]. Reagents used for membrane water purification are low-toxic, permitted to be used for potable water supply, and they are included in to the list of pollutants permitted to be discharged into water bodies, while expenditures for discharge do not exceed 0.5–1.0% of the total operation costs [6].

In Azerbaijan six reciprocating gas engine-driven power plants are in successful operation (Table 1); in their cooling systems, water is demineralized by the membrane technology at the largest of them—the Sangachaly power plant. This water transported by tanker trucks is also used at the remaining five power plants.

**Table 1.** Characteristics of reciprocating engine-driven power plants of Azerbaijan

| Power plant | Installed generating capacity, MW | Number of engines | Amount of components of the cooling liquid, $m^3$ | | | |
|---|---|---|---|---|---|---|
| | | | total mixture | demineralized water | ethylene glycol | corrosion inhibitor |
| Sangachaly | 300 | 18 | 204 | 122–143 | 61–82 | 8.2 |
| Baku | 105 | 12 | 90 | 54–63 | 27–36 | 3.6 |
| Guba | 105 | 12 | 90 | 54–63 | 27–36 | 3.6 |
| Sheki | 87 | 10 | 60 | 36–42 | 18–24 | 2.4 |
| Astara | 87 | 10 | 60 | 36–42 | 18–24 | 2.4 |
| Khachmaz | 87 | 10 | 60 | 36–42 | 18–24 | 2.4 |

Note: Cooling liquid usually consists of 60–70% of demineralized water, 26–36% of ethylene glycol ($HOCH_2CH_2OH$) and about 4% of corrosion inhibitor.

**Table 2.** The physico-chemical composition of the source water (being desalted) and of the permeate (desalted water)

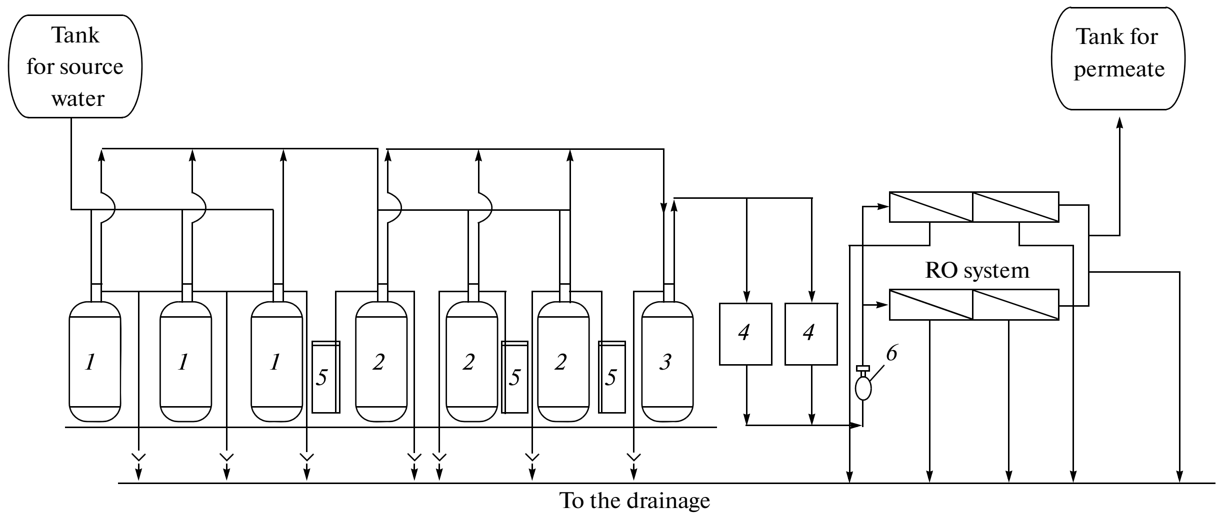
| Indicator | GOST 2874-82 "Potable water" | Source water | Permeate | Filtration efficiency, % |
|---|---|---|---|---|
| pH | 6.0–9.0 | 7.4 | 6.2 | – |
| Total alkalinity $A_{tot} = (HCO_3^- + CO_3^{2-})$: | | | | |
| mg-equiv/dm$^3$ | Not standardized | 3.0 | 0.3 | 90.0 |
| mg/dm$^3$ | | 183.0 | 18.3 | |
| Hydrocarbonates ($HCO_3^-$): | | | | |
| mg-equiv/dm$^3$ | The same | 3.0 | 0.3 | 90.0 |
| mg/dm$^3$ | | 183.0 | 18.3 | |
| Carbonates ($CO_3^{2-}$): | | | | |
| mg-equiv/dm$^3$ | " | 0.0 | 0.0 | – |
| mg/dm$^3$ | | 0.0 | 0.0 | |
| Total hardness $H_{tot} = (Ca^{2+} + Mg^{2+})$: | | | | |
| mg-equiv/dm$^3$ | ≤7 | 5.7 | 0.2 | 96.5 |
| mg/dm$^3$ | ≤225 | 93.62 | 2.82 | |
| Calcium ($Ca^{2+}$): | | | | |
| mg-equiv/dm$^3$ | Not standardized separately | 3.1 | 0.05 | 98.4 |
| mg/dm$^3$ | | 62.0 | 1.0 | |
| Magnesium ($Mg^{2+}$): | | | | |
| mg-equiv/dm$^3$ | The same | 2.6 | 0.15 | 94.2 |
| mg/dm$^3$ | | 36.48 | 1.82 | |
| Chlorides ($Cl^-$): | | | | |
| mg-equiv/dm$^3$ | ≤9.9 | 1.17 | 0.12 | 89.5 |
| mg/dm$^3$ | ≤350.0 | 41.5 | 4.37 | |
| Sulfates ($SO_4^{2-}$): | | | | |
| mg-equiv/dm$^3$ | ≤10.4 | 3.02 | 0.3 | 90.3 |
| mg/dm$^3$ | ≤500.0 | 144.8 | 14.0 | |
| Sodium and Potassium ($Na^+ + K^+$): | | | | |
| mg-equiv/dm$^3$ | ≤8.3 | 1.49 | 0.52 | 65.1 |
| mg/dm$^3$ | ≤200 (Na) | 35.76 | 12.48 | |
| Dry residue, mg/dm$^3$ | ≤1000.0 | 439.0 | 34.0 | 92.2 |

At the Sangachaly power plant located on the Caspian Sea coast, tap water taken from the Kura River is used (Table 2). Such a location of the power plant and the use of potable water for demineralization is very advantageous both economically and ecologically because:

—desalination of tap water is cheaper than that of water with a high salt content [7]; the same applies to brackish water used at the Shimal thermal power station (TPS) [2, 8], and all the more so than sea water [9];

—amount of salts in the concentrate discharged into the sea is 4–5 times lower than in sea water; therefore, its discharge is environmentally safe.

As a rule, it is necessary to provide for measures that must be taken to prevent biological destruction of membranes and deposition of hardly soluble salts on their surfaces. Thus, for this purposes at the Shimal




Schematic diagram of water demineralization at the Sangachaly power plant. *1*—mechanical filters; *2*—Na-cation-exchange filters; *3*—filter with activated charcoal; *4*—cartridge filters; *5*—vessels with NaCl used for regeneration of Na-cation exchange filters; and *6*—booster pump.

TPS and at off-shore oil-production platforms the processes of water disinfection by means of chlorination, acidification up to pH ≈ 5, and introduction of antiscale agents into water are implemented [2, 9].

Such procedures of disinfection and acidification of source water are not implemented at the Sangachaly power plant, because water disinfection is carried out at the city waterworks, while, instead of acidification, Na-cation water softening is used. In principle, operation of the water treatment plant is environmentally clean, because in this plant reagents are not used, except for sodium chloride intended for regeneration of cation-exchange filters.

Thus, the scheme of water demineralization is a combined one (see the figure), but at the Sangachaly power plant water is treated with the use of the technology of ion exchange upstream of the membrane unit, while at the Shimal TPS, downstream of it.

Source water is initially fed to the mechanical filter, in which it is cleared of relatively large particulates. Of the three mechanical filters, in turn the first is in operation, the second, in regeneration, the third, in reserve. Next, water is routed to a Na-cation exchange filter. Of these three filters, again in turn, the first is in operation, the second, in regeneration, the third, in reserve. Thereafter, water sequentially passes through the filter with activated charcoal and through cartridge filters (they can operate either together or in turn, depending on the load). Clarified and softened water is fed by means of the booster pump (under pressure of 6–8 bar) to the apparatus [the reverse osmosis (RO) system having the capacity of about 4000 $dm^3/h$] with membrane elements (Filmtec RO, series TW30 or BW30), in which it is separated into two streams:

—the permeate is directed to the desalted-water tank ($V = 100$ $m^3$);

—the concentrate goes into the drainage (waste water disposal system).

The degree of salt removal is about 92%. The most efficient separation is observed in scale-forming components of hardness salts (for $Ca^{2+}$ – 98.4%, for $Mg^{2+}$ – 94.2%), which provides evidence of a high quality of the permeate (Table 2).

Control over the process of water treatment is carried out in the chemical laboratory from the analyses of water (softened after Na-cation exchange filters and desalted—permeate) once every 24 h, with the use of four indicators: $H_{tot}$, pH, $A_{tot}$, and electrical conduction.

Cleaning of membranes as needed (about once in 2 months) is carried out by means of solutions with the use of reagents allowed for water treatment—sodium tripolyphosphate, sulfuric acid, ethylenediaminetetraacetic acid, citric acid, ammonium hydroxide, etc.

Experience in the operation showed the high degree of the reliability of the technology of the membrane demineralization of water and the efficiency of its implementation in the closed cooling systems at six reciprocating engine-driven power plants in Azerbaijan.

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